**Hess’s Law**

**1.** The equation for the combustion of pentan-1-ol is:

C5H12O(l) + 7½ O2(*g*) → 5CO2(*g*) + 6H2O(l)

Calculate Δc*H* ° for pentan-1-ol, given the following data:

Δf *H* ° (C5H12O(l)) = −295 kJ mol–1

Δf *H* ° (CO2(*g*)) = −394 kJ mol–1

Δf *H* ° (H2O(l)) = −286 kJ mol–1

**2.** An equation for the reaction of ammonia gas with hydrogen chloride gas is:

NH3(*g*) + HCl(*g*) → NH4Cl(*s*)

Calculate the standard enthalpy change, Δr*H°*, for this reaction, using the following data.

Δf *H°* (NH3(*g*)) = –46 kJ mol–1

Δf *H°* (HCl(*g*)) = –92 kJ mol–1

Δf *H°* (NH4Cl(*s*)) = –314 kJ mol–1

**3.** Decane is a component of petrol. Carbon dioxide and water are formed when decane burns completele

in oxygen. C10H22(*ℓ*) + 15 ½ O2(*g*) → 10CO2(*g*) + 11H2O(*ℓ*)

Calculate Δc*H* ° (C10H22 (*ℓ*)), given the following data:

Δf *H* ° (C10H22(*ℓ*)) = –250 kJ mol–1

Δf *H* ° (CO2(*g*)) = –393 kJ mol–1

Δf *H* ° (H2O(*ℓ*)) = –286 kJ mol–1

**4.** Ammonia gas can be oxidised to produce nitrogen monoxide, NO, and water as shown in the equation below:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 4NH3(*g*) | + | 5O2(*g*) | 🡪 | 6H2O(*l*) | + | 4NO(*g*) |

Calculate the enthalpy change, , for this reaction using the information given below.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| N2(*g*) | + | 3H2(*g*) | 🡪 | 2NH3(*g*) |  | = –92 kJ mol–1 |
| 2H2(*g*) | + | O2(*g*) | 🡪 | 2H2O(*g*) |  | = –484 kJ mol–1 |
| N2(*g*) | + | O2(*g*) | 🡪 | 2NO(*g*) |  | = +180 kJ mol–1 |
|  |  | H2O(*l*) | 🡪 | H2O(*g*) |  | = +41 kJ mol–1 |

**5.** An equation for the combustion of octane is: 2C8H18(*ℓ*) + 25O2(*g*) → 16CO2(*g*) + 18H2O(*ℓ*) Calculate Δc*H* °(C8H18(*ℓ*)), given the following data:

Δf *H* °(C8H18(*ℓ*)) = –250 kJ mol–1

Δf *H* °(CO2(*g*)) = –394 kJ mol–1

Δf *H* °(H2O(*ℓ*)) = –286 kJ mol–1

**6. (a)** The equation for the combustion of ethanol is: C2H5OH(*ℓ*) + 3O2(*g*) → 2CO2(*g*) + 3H2O(*ℓ*) Calculate Δc*H* ° (C2H5OH (*ℓ*)), given the following data:

Δf *H* ° (C2H5OH(*ℓ*)) = –277 kJ mol−1

Δf *H* ° (CO2(*g*)) = −394 kJ mol−1

Δf *H* ° (H2O(*ℓ*)) = −286 kJ mol−1

**b)** Use the information below to show that the Δc *H* ° of propene, CH2=CHCH3(*g*), is –2 058 kJ mol–1.

CH2=CHCH3(*g*) + H2(*g*) → CH3CH2CH3(*g*) Δr *H* ° = –124 kJ mol–1

CH3CH2CH3(*g*) Δc *H* ° = –2 220 kJ mol–1

H2O(*ℓ* ) Δf *H* ° = –286 kJ mol–1

**7.** Zinc oxide is formed when zinc sulfide is heated in air.

2ZnS(*s*) + 3O2(*g*) → 2ZnO(*s*) + 2SO2(*g*)

Calculate the enthalpy change, Δr*H*°, for this reaction, using the following data.

Δf *H*° (ZnS(*s*)) = –200 kJ mol–1

Δf *H*° (ZnO(*s*)) = –348 kJ mol–1

Δf *H*° (SO2(*g*)) = –297 kJ mol–1

**8.** Carbon dioxide and water are formed when hexane burns in oxygen.

C6H14(*ℓ*) + 9½O2(*g*) → 6CO2(*g*) + 7H2O(*ℓ*) Δc*H* °= – 4163 kJ mol–1

Calculate the enthalpy of formation of hexane, Δf *H* °(C6H14, *ℓ*).

Δf *H* ° (CO2, *g*) = –393 kJ mol–1

Δf *H* ° (H2O, *ℓ*) = –286 kJ mol–1

**9.** Urea breaks down in moist soil into carbon dioxide and ammonia.

(NH2)2CO(*s*) + H2O(l) → CO2(*g*) + 2NH3(*g*)

Calculate the enthalpy change for this reaction, Δr*H*, using the information below.

(NH2)2CO(*s*) + 3½O2(*g*) → CO2(*g*) + 2H2O(l) + 2NO2(*g*) Δr*H* = –632 kJ mol–1

4NH3(*g*) + 5O2(*g*) → 4NO(*g*) + 6H2O(*g*) Δr*H* = –906 kJ mol–1

NO(*g*) + ½O2(*g*) → NO2(*g*) Δr*H* = –57 kJ mol–1

H2O(l) → H2O(*g*) Δvap*H* = +41 kJ mol–1

**10.** Calculate the heat of combustion of ethyne, Δc*H* C2H2(*g*), from the following data:

2C(*s*) + H2(*g*) → C2H2(*g*) Δr*H* = 229 kJ mol–1

Δc*H* (H-2, *g*) = –285 kJ mol–1

Δc*H* (C, *s*) = –393 kJ mol–1

**11.** Calculate Δf*H*(C2H5OH, *ℓ*) using the following data.

Δc*H*(C2H5OH, *ℓ*) = –1367 kJ mol–1

Δf*H*(CO2, *g*) = –394 kJ mol–1

Δf*H*(H2O, *ℓ*) = –286 kJ mol–1

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